Tertiary Echinoids from Papua New Guinea

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Tertiary echinoid faunas from four different environments are described from three localities in Papua New Guinea (PNG). The fauna from the Middle Miocene Langimar Beds at Aseki village, Morobe Province, is dominated by near-surface, sand dwelling clypeasteroid echinoids *Echinodiscus bisperforatus* Leske, 1778 and *Laganum depressum* Lesson in L. Agassiz, 1841. The fauna from the Upper Oligocene-Lower Miocene Padowa Beds in the Sagarai valley, Milne Bay Province, is dominated by sand and sandy-mud burrowing spatangoid echinoids *Brisaster latifrons* (A. Agassiz, 1898) and *Brissopsis ?luzonica* (Gray, 1851). The rich echinoid fauna from the Lower Pliocene Kairuku Formation on Yule Island, Central Province, includes sea-grass meadow dwelling, and highly turbulent, shallow-water dwelling forms. The fauna includes the clypeasteroid echinoids *L. depressum* and fibulariid (?)gen. et sp. nov., a temnopleurid echinoid *Temnotrema macleayana* (Tenison-Woods), a phymosomatoid echinoid stomechinid (?)gen. et sp. nov., and spatangoid echinoids *B. latifrons* and *Ditremaster* sp. indet. Five of the eight described echinoid genera from the Tertiary of PNG still live in waters of the Indo-Pacific today.

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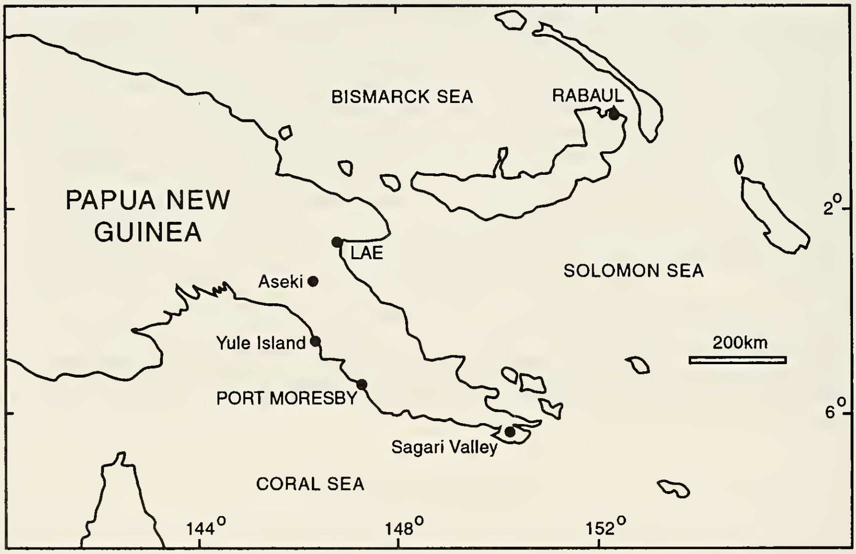
KEYWORDS: Echinoidea, *Echinodiscus*, *Laganum*, *Brisaster*, *Brissopsis*, *Temnotrema*, *Ditremaster*, fibulariid, stomechinid, Tertiary, Papua New Guinea.

INTRODUCTION

Echinoids are a not uncommon component of Tertiary faunas of Papua New Guinea (PNG), but little systematic work on them has been completed. Tenison-Woods (1878) provided the first description of PNG Tertiary echinoids, describing the temnopleurid *Temnechinus macleayana* Tenison-Woods, 1878 and noting the occurrence of the clypeasteroid *Peronella decagonalis* Lesson in A. Agassiz, 1872. This material was probably collected from the Lower Pliocene Kairuku Formation on Yule Island, northwest of Port Moresby. Jack and Etheridge (1892) provided a further description of Tenison-Woods' (1878) material. Echinoids were also noted by Maitland (1892) from lateral equivalents of the Kairuku Formation near Delena, 3 km south-southeast of Yule Island. Chapman (1914) recorded indeterminate echinoid plates and spines from a limestone on the eastern side of Bootless Inlet, southeast of Port Moresby. This limestone, known as the Bootless Inlet Limestone, is of Upper Oligocene-Lower Miocene age (Tertiary Letter Stage lower Te) (Pieters 1978). Further consideration of Yule Island and Delena echinoid faunas appeared in reports of the Anglo-Persian Oil Company, when F. Chapman and I. Crespin (in Montgomery 1930) noted the cidaroids *Phyllacanthus javanus* K. Martin, 1885 and *P. sundaica* K. Martin, 1885, the clypeasteroids *Laganum* sp., *L. depressum* Lesson in L. Agassiz, 1841, *L. bonani* Klein, 1734, *L. elongatum* L. Agassiz, 1841, *Arachnoides placenta* (Linnaeus), *A.* cf. *placenta*, *Peronella* sp. and *Fibularia* sp., the spantangoids *Eupatagus pulchella* (sic) (Herklots), *Brissopsis* sp. and *Hemiaster* sp., and the camarodonts *Pleurechinus javanus* (Martin) and *Echinus* cf. *stracheyi*. Numerous fragmentary echinoid remains were observed in surface and subsurface Tertiary formations in western Papua and New Guinea during the exploration work of Carne (1913), the Anglo-Persian Oil Company (1920-1929) and the Australasian Petroleum Company (1937-1961).

Although several cladistic classifications have recently been proposed for echinoids (Jensen 1981; Smith 1984), and the clypeasteroids in particular (Wang 1984; Mooi 1990a, 1990b), the classsification used herein follows that of McCormick and Moore (1966). Cladistic attempts at classification, such as Mooi (1990a), have relied heavily on characters usually only evident in extant forms, including external appendages, Aristotle's lantern anatomy and test structure, and are not readily applicable to the fossil specimens used in this study. Collection details are provided in the Appendix. All specimens are housed in the Department of Geology, Australian National University, Canberra.

Figure 1. Papua New Guinea, showing Aseki, Sagarai valley and Yule Island echinoid localities.



STRATIGRAPHY AND ECHINOID FAUNAS

The echinoids described in this paper were collected at Aseki village in Morobe Province, the Sagarai valley in Milne Bay Province, and Yule Island in Central Province (Fig. 1), and represent four contrasting facies controlled assemblages.

The echinoid fauna from Aseki was collected from a rubble of lithic sandstone developed on the Langimar Beds (Fig. 2). The Langimar Beds crop out in a 120 km belt straddling the flanks of the Owen Stanley Ranges, west of Wau and Bulolo (Smit et al. 1974). The formation consists of conglomerate, sandstone, interbedded marl, mudstone and calcarenite, passing southwards to silty mudstone, siltstone and sandstone with interbedded biohermal limestone, interpreted by Smit et al. (1974) as a shelfal facies. Abundant foraminifera in calcareous beds in the formation indicate a Middle Miocene (Tertiary Letter Stage lower Tf) age (Dow et al. 1974). The fauna is dominated by the

Figure 2. Aseki locality, Menyamya district, Morobe Province.

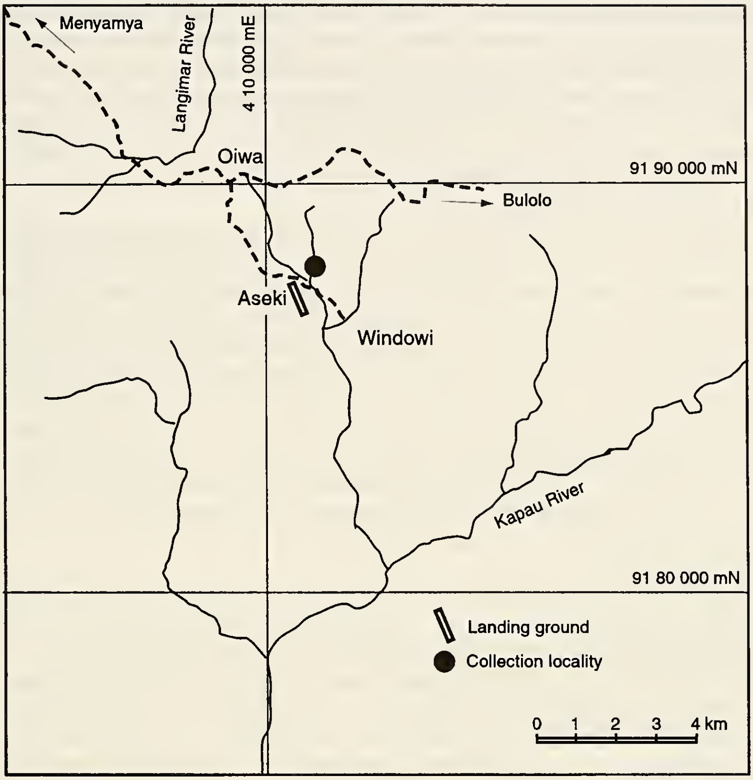
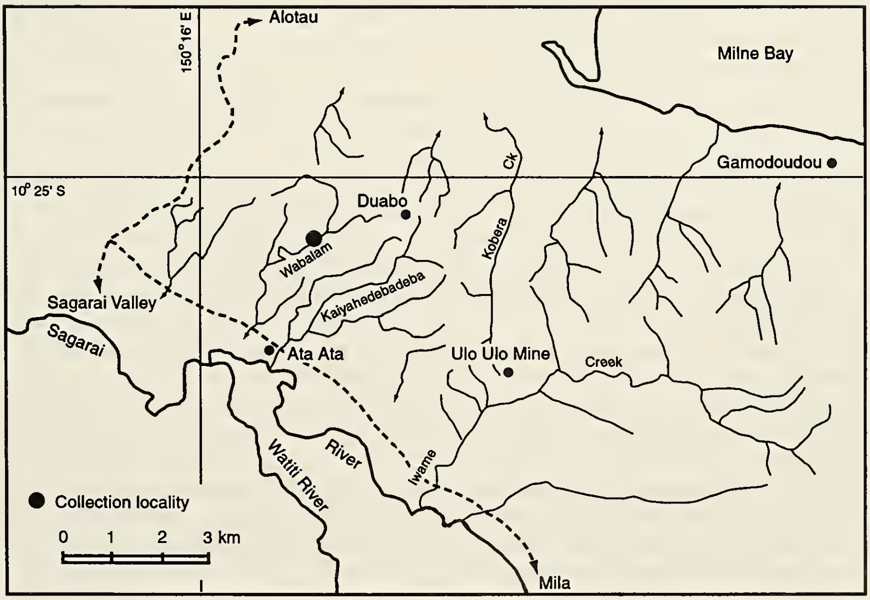


Figure 3. Sagari valley locality, southwest of Alotau, Milne Bay Province.



clypeasteroids *Echinodiscus bisperforatus* Leske, 1778 and *Laganum depressum* Lesson in L. Agassiz, 1841. Both species are today widely distributed throughout the tropical and sub-tropical Indo-West Pacific. The Aseki echinoids are preserved in a fine-medium grained sand, typical of the sandy habitats occupied by modern clypeasteroids. In their life position, they probably burrowed in the uppermost sand layer, from which they obtained their food by particle-sieving (Seilacher 1979). Today, living clypeasteroids occupy extreme variants of the sandy habitat, as intertidal browsers, epibenthic deposit feeders in sea-grass meadows, surf dwellers, and stationary suspension feeders in the protected sands of bays (Seilacher 1979).

Echinoids from the Sagarai valley were collected from exposures along a tributary of the Sagarai River (Fig. 3). Smith and Davies (1972) mapped these gently dipping tuffaceous sandstone exposures as the Padowa Beds. Delicately preserved echinoid tests are abundant at this locality and occur with gastropods, pelecypods, solitary corals and "larger" foraminifera. Foraminifera indicate an Upper Oligocene-Lower Miocene age (Tertiary Letter Stage Te) for the formation (D.J. Belford in Smith and Davies 1973). The burrowing spatangoids *Brisaster latifrons* (A. Agassiz, 1898) and *Brissopsis ?luzonica* (Gray, 1851), with deep anterior grooves, appear to have been dominant in the sand-sandy mud substratum of this locality. Excellent preservation is a function of their infaunal mode of life (Kier 1977). Both species are known in the Indo-Pacific today. *Brissopsis luzonica* is a common form in tropical and sub-tropical waters (Clarke and Rowe 1971; De Ridder 1986), whereas *B. latifrons* appears to be restricted to sub-tropical and cooler waters (Mortensen 1951).

The Yule Island specimens were collected from friable bioclastic limestone of the Lower Pliocene (zone N18-N19/20: Haig et al. 1993) Kairuku Formation. This inner-neritic carbonate sand facies includes coral-rich beds and *Marginopora*-rich sands, interpreted to have accumulated in sea-grass meadows (Haig et al. 1993). The rich echinoid fauna is dominated by infaunal irregular forms including clypeasteroids *L. depressum* and an unnamed fibulariid, and spatangoids *Ditremaster* sp. indet. and *B. latifrons*. Epifaunal echinoids are typically small and include the temnopleurid *Temnotrema macleayana* (Tenison-Woods, 1878) and an unnamed stomechinid.

Some of the Yule Island echinoids were members of a predominantly infaunal sea-grass community, confined to coarse-grained sand in shallow water. A highly turbulent, nearshore niche of creviced rock with pockets of sand was inhabited by *T. macleayana*, the stomechinid and the fibulariid. The test of *T. macleayana* is thick and strong and has a well-developed sutured plating, enabling it to withstand increased impact loading (Smith 1984), and allowing it to live in a highly turbulent shallow-water habitat. The stomechinid has a flattened test with a low down ambitus, an adaptation giving stability in currents on either rocky or sedimentary substrata. The fibulariid is distinctive for its well-developed marginal frill spines, and *Mellita lata* H.L. Clark, 1940, a common Carribean clypeasteroid that lives in sand of the breaker zone, is useful for comparative purposes. This species uses its frill spines for burrowing and, by bending them down, to reduce shifting (Seilacher 1979).

Tertiary echinoid faunas of the surrounding region have been described from the Indonesian archipelago (Jeannet and Martin 1937) and Barrow Island, off the Pilbara coastline of northwestern Australia (McNamara and Kendrick 1994). The Barrow Island limestones represent the most northerly surface exposure of Miocene marine deposits in Australia (McNamara and Kendrick 1994), and their echinoid fauna is therefore of significance in relation to Tertiary faunas in PNG. McNamara and Kendrick (1994) noted that the Barrow Island fauna is typically tropical in nature, having strong affinities with those from the Miocene deposits of India and Java. By contrast, the strong links between Indo-West Pacific Miocene faunas do not exist with the well-documented faunas from the Miocene of southern Australia (McNamara and Kendrick 1994). All of McNamara and Kendrick's (1994) recorded genera still live in the Barrow Island area today.

There are no genera in common between the PNG and Barrow Island echinoid faunas, and this faunal mismatch may, to some extent, be influenced by facies differences. However, affinities with the Mio-Pliocene of the Indonesian archipelago are stronger, with *Echinodiscus*, *Laganum* and *Temnotrema* identified in both faunas. Five of the eight described echinoid genera from the Tertiary of PNG still live in waters of the Indo-West Pacific today.

SYSTEMATIC PALAEONTOLOGY

Class ECHINOIDEA Leske, 1778
Subclass EUECHINOIDEA Bronn, 1860
Superorder ECHINACEA Claus, 1876
Order TEMNOPLEUROIDA Mortensen, 1942
Family TEMNOPLEURIDAE A. Agassiz, 1872
Genus TEMNOTREMA A. Agassiz, 1863

Type species

Temnotrema sculptum A. Agassiz, 1872, by original designation.

Temnotrema macleayana (Tenison-Woods)
Figs 4d-f, 5

Synonymy

Temnechinus Macleayana Tenison-Woods, 1878, p. 126; Etheridge 1889, p. 173, 178; Etheridge 1892, p. 209, 214; Jack and Etheridge 1892, p. 691.
Temnechinus Macleayi (sic) Tenison-Woods; Tate 1894, p. 213, 214.
Temnechinus Macleaya (sic) Tenison-Woods; Carne 1913, p. 17.
Pleurechinus javanus (Martin); F. Chapman and I. Crespin in Montgomery 1930, p. 58.
Dicoptella agassizi Lambert and Thiéry; Lambert and Jeannet 1935, p. 34.
Dicoptella agassizi var. *tenuis* Jeannet in Lambert and Jeannet 1935, p. 34.
Dicoptella agassizi var. *elevata* Jeannet in Lambert and Jeannet 1935, p. 34.
Dicoptella leupoldi Jeannet in Lambert and Jeannet 1935, p. 38.
Dicoptella tobleri Jeannet in Lambert and Jeannet 1935, p. 39.
Dicoptella cf. *tobleri* Jeannet in Lambert and Jeannet 1935, plate 2: figs 13-15.
Dicoptella javana Jeannet in Lambert and Jennet 1935, p. 40.
Temnotrema macleayana (Tenison-Woods); Philip 1969, p. 235.

Description

Test small, 13 mm diameter, hemispherical with oral surface sunken around peristome, thick and strong. Details of apical system unknown. Ambulacra at ambitus are about 2/3 as wide as interambulacra. Ambulacral plates compound, composed of three individual plates each bearing pore pair; pores in straight series, small, equal sized. A prominent elevated primary tubercule is present in the middle of each plate; tubercules are imperforate and noncrenulate. Primary tubercules form a distinct vertical series; each tubercule surrounded adapically by a semi-circular row of secondary tuberculation. Large deep, elongate-ovoid sutural pits excavated at end of horizontal suture between adjacent plates. Interambulacral plates about equal in height to opposite ambulacral plate. Each possesses a prominent imperforate, noncrenulate primary tubercule; elevated, occurring in the middle of each plate. Tubercules form two regular vertical series. Irregular secondary tubercules surround each primary tubercule on all plates. Deeply excavated elongate-ovoid sutural pits present at medial and adradial end of all horizontal sutures; pits spaced well apart on oral and apical surfaces. Peristome moderate, 1/4 of horizontal diameter; gill slits indistinct; other details of peristome unknown.

Remarks

Temnotrema A. Agassiz, 1863 is a Miocene-Recent temnopleurid with many species. The Recent species of *Temnotrema* (numbering at least 13) are, like most temnopleurids, warm water forms and are distributed throughout the Indo-Pacific (Red Sea to Hawaii, Japan to Australia) (Mortensen 1943; Fell and Pawson 1966). Fossil species of *Temnotrema* are known from the Miocene of Java and Borneo and the Pliocene of Indonesia (Fell and Pawson 1966). Several species with strong affinities to *T. macleayana* have been described from the Miocene of Java (Lambert and Jeannet 1935; Philip 1969: p. 235).

The Yule Island species of *Temnotrema* was originally assigned to *Temnechinus* by Tenison-Woods (1878) because of affinities with *Temnechinus lineatus* Duncan, 1877, from the Pliocene Sandringham Sand, Port Philip Bay, and *Temnechinus globosus* Forbes, 1852, from the Pliocene of England. *T. lineatus* has subsequently been designated as the type species of *Otholophus* Duncan, 1887, and some writers (Lambert and Thiéry 1910) have referred *T. globosus* to *Dicoptella* Lambert, 1907, now regarded as a synonym of *Temnotrema* (Mortensen 1943). Etheridge (1889, 1892) and Tate (1894) expressed doubt about Tenison-Woods' (1878) generic assignment. Etheridge (1892: 214) considered that the test 'does not possess the typical excavations along the sutural margins of plates seen in all true forms of *Temnechinus*, nor are the ambulacral plates confluent'.

Figure 4. Regular echinoids. Stomechinid (?)gen. et sp. nov. Lower Pliocene, Yule Island, Central Province. 4a-c, UPNG F1184, aboral, oral and lateral views. *Temnotrema macleayana* (Tenison-Woods). Lower Pliocene, Yule Island, Central Province. 4d-f, UPNG F1181, aboral, oral and lateral views. Bar scale = 0.5 cm.

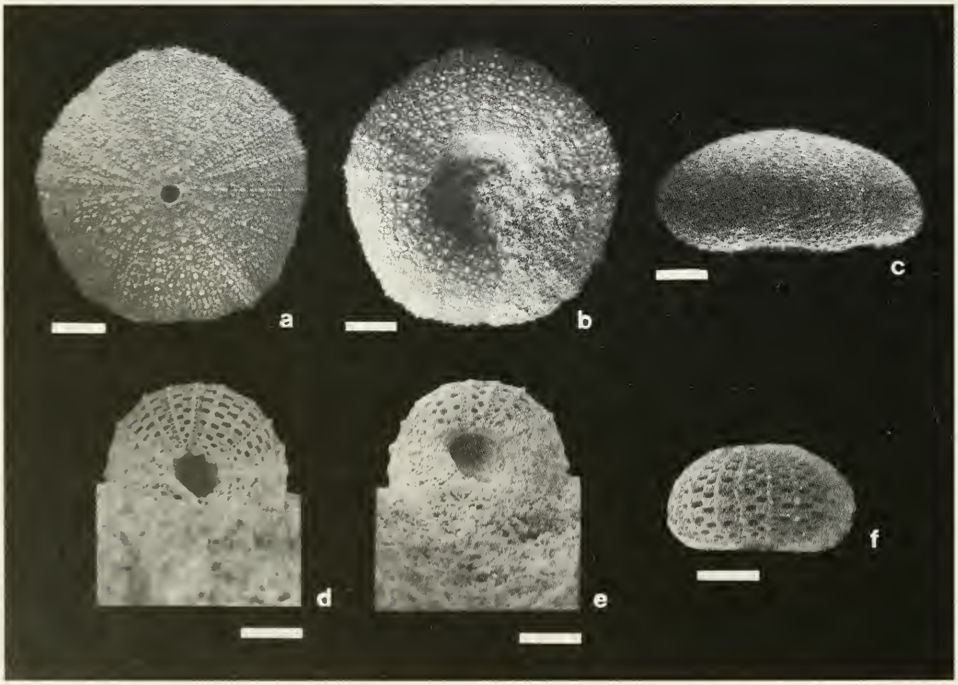
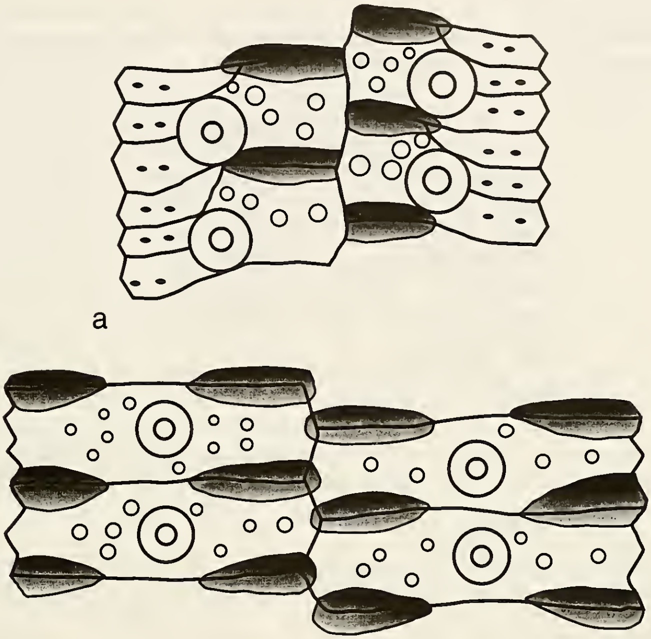


Figure 5. *Temnotrema macleayana* (Tenison-Woods). Lower Pliocene, Yule Island, Central Province. 5a,b, UPNG F1181, plating diagrams at ambitus for ambulacrum, interambulacrum.



a

b

Mortensen (1943: 246) noted that details of spines, the pedicellariae, periproct and colour are of importance in identifying tests of Recent temnopleurids, and for fossil species, where details of tuberculation and the shape of sutural pits provide species distinction, identifications are very unreliable. Philip (1969) echoed these concerns, noting a preoccupation of previous work on fossil temnopleurids 'with minor details of the sculpture or ornament for the purposes of taxonomic discrimination - which features are acknowledged to be exceedingly variable in adequately known species'. Palaeontologists have answered this problem of variation 'by naming extremes of variation in an assemblage' (Philip 1969).

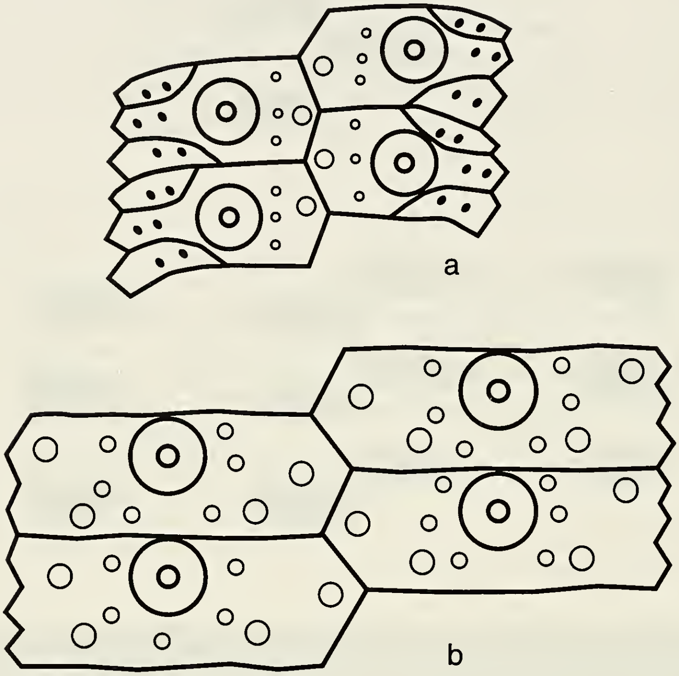
The nature of sutural plating for the Yule Island species of *Temnotrema* is very similar to that described for *Temnechinus* by Forbes (1852). The arrangement of pore pairs is regarded as a significant distinction between both forms. The pore pairs of *T. macleayana* are arranged in a straight series, contrasting with those of *Temnechinus*, with pairs arranged in oblique arcs of three.

Philip (1969) noted a twofold subdivision of fossil temnopleurids using test morphology, viz. forms with a sculptured test, and those with sutural pits. He noted that all Australian Tertiary temnopleurid species are sculptured forms, with the pitted forms well represented in the Indo-Pacific. *T. macleayana* clearly falls within the Indo-Pacific realm. Smith (1984) interpreted the evolution of sutured plating as an important advance that allowed an increase in shock-resistance capabilities of the test, allowing echinoids to invade highly turbulent shallow-water habitats.

Material

UPNG F1181, a complete test from the Kairuku Formation, Yule Island, Central Province, PNG. Lower Pliocene.

Figure 6. Stomechinid (?) gen. et sp. nov. Lower Pliocene, Yule Island, Central Province. 6a,b, UPNG F1184, plating diagrams at ambitus for ambulacrum, interambulacrum.



Order PHYMOSOMATOIDA Mortensen, 1904
Family STOMECHINIDAE Pomel, 1883
Genus UNCERTAIN (?nov.)

Stomechinid (?) gen. et sp. nov.
Figs 4a-c, 6

Description

Test small, 20 mm diameter, subhemispherical, height of test about 1/2 of its diameter. Ambitus relatively low, rounded pentagonal outline. Oral surface distinctly concave. Apical system small, with central periproct. Ambulacra at ambitus are about 1/2 width of interambulacra. Ambulacral plates compound, trigeminate, pore pairs in arcs of three. A prominent elevated primary tubercule in present in the middle of each plate, forming vertical series. Tubercules imperforate, noncrenulate, as large as interambulacral primaries. Secondary tubercules, not as large as primaries, with a tendency to align in a vertical series on medial side of primary tubercule. Interambulacral plates about equal in height to opposite ambulacral plate. Each possesses a central prominent imperforate, noncrenulate primary tubercule; surrounded by annulus of smaller secondaries, inturn flanked by about four larger secondaries. Peristome large, about 1/3 horizontal diameter of test; gill slits are distinct; other details of peristome unknown.

Remarks

The Yule Island specimen with its large peristome (typical of all stirodont orders), imperforate primary tubercules and trigeminate ambulacral plates can be clearly placed in Order Phymosomatoida. The specimen's noncrenulate primary tubercules, with ambulacral primaries as large as interambulacral primaries, and a large peristome with distinct gill slits readily places it in Family Stomechinidae. The stomechinids include 21 genera ranging from the Lower Jurassic-Recent (Fell and Pawson 1966). The low hemispherical test with rounded pentagonal ambital outline is distinctive, but formal description of the single Yule Island specimen is deferred until more material is available. *Trochalosoma* Lambert, 1897 from the Late Cretaceous of Jamaica has a similar ambital outline with trigeminate ambulacral plates, but the test is flattened and wheel-shaped (Fell and Pawson 1966). Similarly, both *Gomphechinus* Pomel, 1883 from the Late Cretaceous of North Africa and Madagascar, and *Phymechinus* Desor, 1856 from the Middle Jurassic-Late Cretaceous of Europe, are polyporous forms that possess an ambitus that is low down, but their test outline is circular (Fell and Pawson 1966).

The noticeably low hemispherical profile of the Yule Island test, with a low down ambitus with subrounded outline, is similar to that described for *Holectypus depressus* (Leske), a Jurassic irregular echinoid (Smith 1984). Its test shape was interpreted by Smith (1984: 101) to be an adaptation giving stability in currents on either rocky or sedimentary substrata, or an adaptation for burrowing. The lack of any difference in size or shape between oral and apical tubercules on the Yule Island test suggests that burrowing was unlikely.

Material

UPNG F1184, a complete test from the Kairuku Formation, Yule Island, northwest of Port Moresby, Central Province, PNG. Lower Pliocene.

Superorder GNATHOSTOMATA Zittel, 1879
Order CLYPEASTEROIDA A. Agassiz, 1872
Suborder SCUTELLINA Haeckel, 1896
Family ASTRICLYPEIDAE Stefanini, 1911
Genus ECHINODISCUS Leske, 1778

Type species

Echinodiscus bisperforatus Leske, 1778, by subsequent designation of ICZN, 1950; Recent, Indo-Pacific.

Echinodiscus bisperforatus Leske, 1778
Fig. 7d

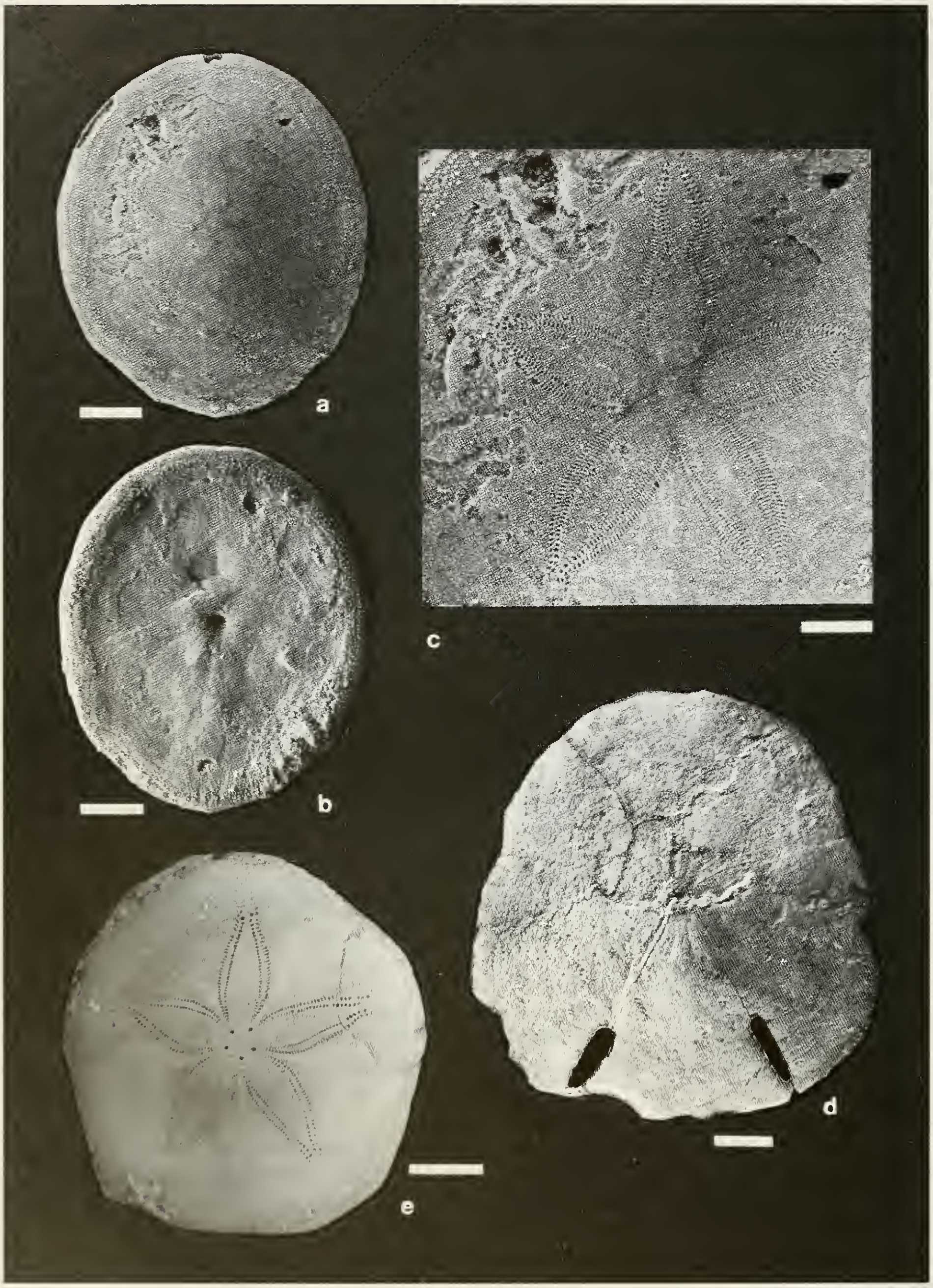
Synonymy

Echinodiscus bisperforatus Leske, 1778, p. 196.
Echinodiscus bisperforatus truncatus (L. Agassiz), H.L. Clark, 1914, p. 72.
T. Mortensen (1948), A Monograph of the Echinoidea 4(2), Clypeasteroida, p. 406 and p. 410, lists the previous synonymies.

Description

Test of medium size 65 mm x 70 mm, low discoidal with semi-circular outline, mostly truncate at the posterior end. Apical system is central; petals straight, narrow and short, extending slightly less than one-half distance to margin; distinctly closed distally; pore zones slightly less than the width of interpore zones. Details of apical system unknown. Two closed lunules or slits in the posterior ambulacra, narrow, about as long as the petals. Details of oral surface unknown.

Figure 7. Clyperasteroid echinoids. Fibulariid (?) gen. et sp. nov. Lower Pliocene, Yule Island, Central Province. 7a-b, UPNG F1183, aboral, oral views. Bar scale = 0.5 cm; 7c, UPNG F1183, detail of apical system showing ambulacral position of genital pores. Bar scale = 0.25 cm. *Echinodiscus bisperforatus* Leske, 1778. Middle Miocene, Aseki village, Morobe Province. 7d, ANU 60549, aboral view. Bar scale = 1.0 cm. *Laganum depressum* Lesson in L. Agassiz, 1841. Lower Pliocene, Yule Island. 7e, UPNG F1182, aboral view. Bar scale = 0.5 cm.



Remarks

The author follows Clark and Rowe's (1971) key which, for *Echinodiscus*, used lunule length relative to test radius or petal length as a diagnositic character. The possession of closed posterior lunules of a similar length to petals clearly indicates assignment of the Aseki specimen to *Echinodiscus bisperforatus* Leske, 1778. *E. tenuissimus* (L. Agassiz, 1847), a similar species in many respects, possesses lunules shorter than petals. Although Mortensen (1948: 409) observed that the length of lunules varies very considerably within this species, it is useful to note that the lunules of the Aseki specimen are at most about as long the petals, a diagnostic character of var. *truncatus* (L. Agassiz, 1841). The status of *Echinodiscus bisperforatus truncatus* is unclear. Clark and Rowe (1971) did not recognise var. *truncatus* in their monograph of extant Indo-West Pacific echinoderms, whereas De Ridder (1986) described its occurrence in New Caledonia. Mortensen (1948) described an Indo-West Pacific distribution for both the main form and the var. *truncatus*, from the Red Sea and East Coast of Africa to New Caledonia, with no record from the Philippines and farther north.

Mortensen (1948) did not record any fossil species of *Echinodiscus* Leske, 1778, but Durham (1966) noted a Miocene-Recent range for the genus. The amended range clearly includes the Aseki specimen.

Material

ANU 60549, a complete test from the Langimar Beds, headwater course of a small tributary of the Kapau River, Aseki village, Morobe Province, PNG. Middle Miocene.

Suborder LAGANINA Mortensen, 1948
Family LAGANIDAE A. Agassiz, 1873
Genus LAGANUM Klein, 1734

Type species

Laganum petalodes Link, 1807, by original designation.

Laganum depressum Lesson in L. Agassiz, 1841
Fig. 7e

Synonymy

?*Echinarachnius conchatus* M'Clelland, 1840, p. 181.
Laganum multiforme K. Martin, 1880, p. 3.
Laganum depressum Lesson in L. Agassiz, 1841, F. Chapman and I. Crespin in Montgomery 1930, p. 57.
Laganum boschi Jeannet and Martin, 1937, p. 253.
T. Mortensen (1948), A Monograph of the Echinoidea 4(2), Clypeasteroida, p. 313, lists the previous synonymies.

Description

Test flattened with rounded pentagonal outline; length of test varies from 28 to 32 mm, the length exceeding the breadth; broadest at the antero-lateral petals. Test of F1182 is weakly reenteringly curved in the interambulacra. Edge of test is inflated forming a broad margin; inside inflated margin the test is somewhat sunken, then rises to the apical system. The oral surface is weakly concave. Apical system central and raised; pentagonal with apices opposite interambulacra. Petaloid area is large, about 2/3 the test length, the petals reaching the marginal inflated region. Genital pores five, located at adapical end of interamulacra. Petals are relatively broad, closed distally. The anterior petal of F1180 is slightly longer than others. Pore pairs consist of inner, smaller circular pore and outer, larger elongated pore. Interporiferous zone is covered by scattered primary tubercles amongst miliary tubercles. Tuberculation on remainder of aboral surface and on oral surface consists of similarly scattered primary tubercules amongst numerous miliary tubercles. The periproct of F1180 near posterior edge of test, c. 25 per cent of distance from mouth to posterior edge; transversly elongate. Details of peristome and ambulacral furrows unknown.

Remarks

Laganum is an Eocene-Recent clypeasteroid (Durham 1966) with numerous fossil and extant species (Clark 1938; Jeannet and Martin 1937; Mortensen 1948; De Ridder 1986). *Laganum depressum* Lesson in L. Agassiz, 1841 is a well known Recent species widely distributed throughout the tropical and sub-tropical Indo-West Pacific (Mortensen 1948). Fossil *L. depressum* are recorded from the ?Miocene-Pleistocene (Mortensen 1948). The ?Miocene occurrence of the species is from Fiji (Mortensen 1948). *Laganum multiforme* K. Martin, 1880 and *Laganum boschi* Jeannet and Martin, 1937, both described from the Pliocene of Java by Jeannet and Martin (1937), are considered as identical to *L. depressum* by Mortensen (1948). The Yule Island specimens are identical in almost all respects to Recent specimens examined by the writer from the south coast of New Britain, PNG, and the Philippines. The fossil tests are comparatively thinner than Recent tests, probably a result of compaction by enclosing sediment during lithifaction.

Material

Three tests: two complete tests UPNG F1180 and F1182 from the Kairuku Formation, Yule Island, northwest of Port Moresby, Central Province and ANU 60556, a poorly preserved test from the Langimar Beds, tributary of the Kapau River, Aseki village, Morobe Province, PNG. Middle Miocene-Lower Pliocene.

Family FIBULARIIDAE Gray, 1855
Genus UNCERTAIN (?nov.)

Fibulariid (?) gen. et sp. nov.
Figs 7a-c

Synonymy

Peronella decagonalis Lesson in A. Agassiz, 1872-74; Tenison-Woods 1878, p. 126; Etheridge 1889, p. 173, 178; Etheridge 1892, p. 209, 215; Jack and Etheridge 1892, p. 692; Tate 1894, p. 213, 214; Carne 1913, p. 17 [non *Laganum decagonale* (Blainville, 1827)].

Peronella sp., F. Chapman and I. Crespin in Montgomery 1930, p. 57.

Echinodiscus lesueuri: Jeannet and Martin 1937, p. 254 [non *Peronella lesueuri* Valenciennes in L. Agassiz, 1841].

Description

Test markedly flattened with elliptical outline; length of 35 mm; broadest at the anterolateral petals; edge of test is weakly inflated forming a narrow margin. The apical system raised and slightly anterior; composed of single large madreporite plate; stellate with apices opposite interambulacra. Genital pores five, located midway along sides of central plate, at adapical end of ambulacra (Fig. 7c). Petaloid area is large, about 2/3 test length. Petals are relatively narrow and closed distally; the anterior petal is slightly longer than the others. Plates of petals apparently simple, running across half the width of the petal. Pores small, about equal sized, conjugate. Interporiferous area is fairly narrow, covered by scattered primary tubercles and numerous miliary tubercules. Most of the remainder of aboral surface is covered by scattered coarse primary tubercles and fine miliary tubercles; densely spaced primary tubercles are present around edge of test on the weakly inflated margin. Pattern of tuberculation on the oral surface is similar to that of the aboral surface. Oral surface shallowly concave; ambulacral furrows absent. The periproct is transversely elongate; nearer the posterior margin than the mouth.

Remarks

There are no food grooves on the well preserved oral surface of the Yule Island test and although, as pointed out by the anonymous reviewer, the flattened body and well developed petals are typically laganid, the specimen is tentatively assigned to Family Fibulariidae. Durham (1966) and Smith (1984) attached considerable importance to food grooves and the nature of their branching in their classification of the clypeasteroids. Clypeasteroids lacking food grooves were assigned to Family Fibulariidae. By contrast, Mooi (1990a) gave little attention to food grooves in his cladistic classification of the order.

The fibulariids according to Durham's (1966) classification include a diverse group of species, typically small, but with very variable test shape and petals, ranging from the Paleocene-Recent (Kier 1982). Durham (1966) and Kier (1982) regarded many of the characters of fibulariids as primitive and, with their relative stratigraphic position, the family was interpreted to represent the ancestral stock of other clyperasteroids. Mooi (1990a) presented an opposing view, that the fibulariids were highly specialised forms not at all representative of an ancestor to the clypeasteroids.

Fossil fibulariids from the region include *Fibularia gregata* Tate, 1885 and *Scutellina patella* Tate, 1891 from the Eocene-Miocene and Eocene, respectively, of Australia (Tate 1891) and *Echinocyamus* sp. and *Fibularia rhedeni* Jeannet, 1937 from the Lower Miocene and Oligocene-Miocene, respectively, of the Indonesian archipelago (Jeannet and Martin 1937). McNamara and Kendrick (1994) noted the presence of poorly preserved *Fibularia* sp. from the Middle Miocene of Barrow Island, off the Pilbara coast of Western Australia.

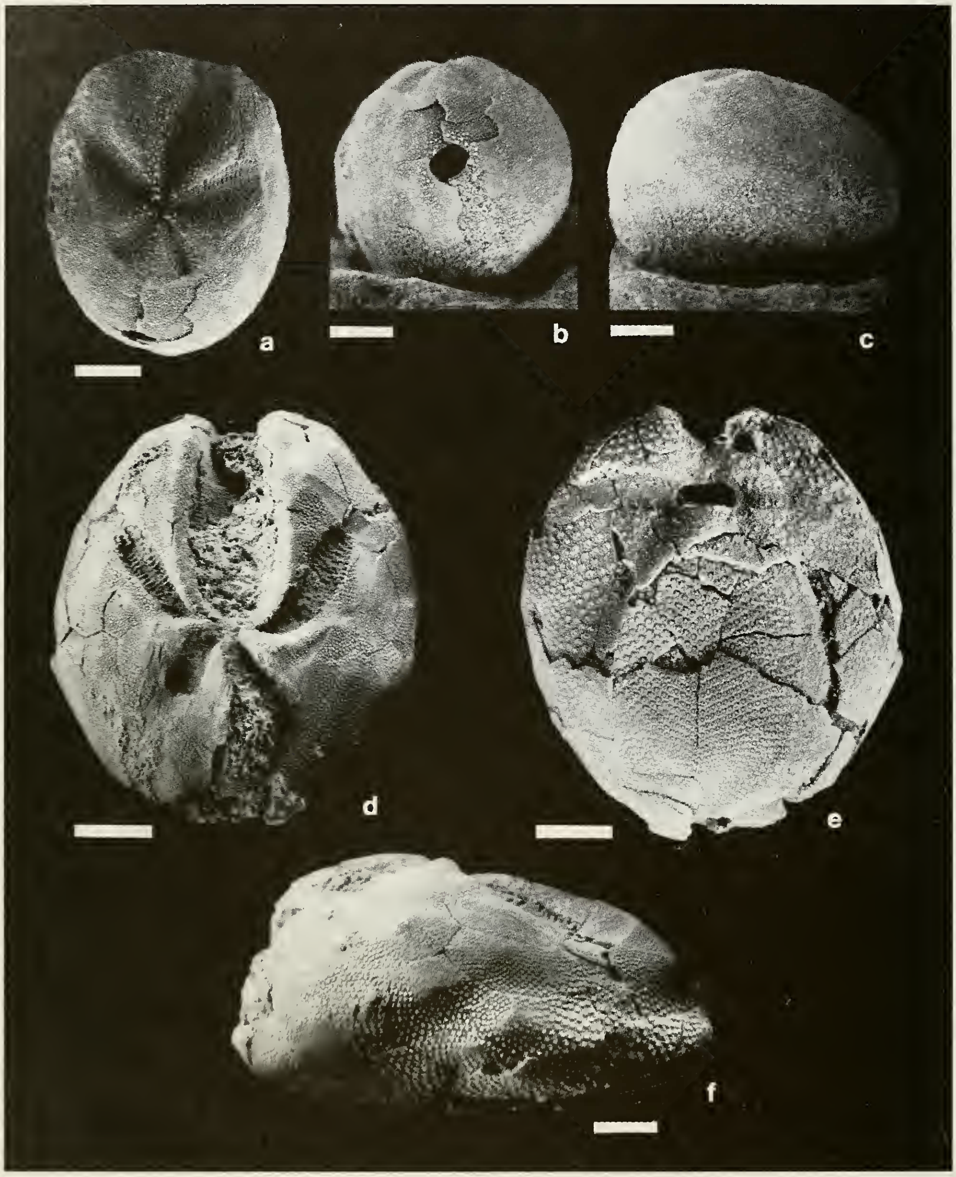
Although the Yule Island specimen is tentatively assigned to Family Fibulariidae, generic assignment of this single specimen is problematical and circumstances do not permit collection of additional material. Two characters appear to distinguish it from other fibulariids. Firstly, the position of the genital pores midway along the sides of the large stellate madreporite plate, a condition found in some apical systems of the monobasal Clypeasteroidea (Melville and Durham 1966: U229), does not appear to be present in the fibulariids. Secondly, the test's size is significantly larger than for other fibulariids. Tenison-Woods' (1878) specimen measured about 25 mm diameter and the present specimen 35 mm.

The small size of the fibulariids allows food to be passed directly to the mouth by tube feet, obviating the need for oral ambulacral food grooves along which food particles are transported to the mouth in mucus strings (Seilacher 1979; Smith 1984). This method of food gathering was also used by early clypeasteroids. The presence of frill spines in an outer margin position, indicated by densely spaced tubercules around the edge of the Yule Island test (Figs 7a,b), served to sieve sand and also probably act as a steering device during burrowing (Seilacher 1979).

Material

UPNG F1183, a complete test from the Kairuku Formation, Yule Island, northwest of Port Moresby, Central Province, PNG. Lower Pliocene.

Figure 8. Spatangoid echinoids. *Ditremaster* sp. indet. Lower Pliocene, Yule Island, Central Province. 8a-c, UPNG F1186, aboral, posterior and lateral views. *Brisaster latifrons* (A. Agassiz, 1898). Lower Pliocene, Yule Island, Central Province. 8d-f, UPNG F1179, aboral, oral and lateral views. Bar scale = 0.5 cm.



Superorder ATELOSTOMATA Zittel, 1879
Order SPATANGOIDA Claus, 1876
Suborder HEMIASTERINA Fischer, 1966
Family HEMIASTERIDAE Clark, 1917
Genus DITREMASTER Munier-Chalmas, 1885

Type species

Hemiaster nux Desor, 1853, by subsequent designation of Cotteau, 1887; Eocene, France.

Ditremaster sp. indet.
Figs 8a-c

Description

Test small with ovoid outline; sub-globular, rather high, vaulted. Test outline weakly notched at the frontal ambulacrum. Apical system subcentral, ethmophract, with madreporite not separating posterior oculars. Two gonopores, although genital 5 in F1186 appears to be perforated by two pores. Mortensen (1948: 316) noted similar genital pore doubles in clypeasteroid species. Frontal sinus slight. Petals well developed, straight, closed, somewhat sunken, the posterior pair very short, about 1/3 length of anterior ones. Pores small, elongate and conjugate. Scattered granules present in interporiferous and pore zones. Peripetalous fasciole well developed but no other fascioles. Periproct at upper end of curved posterior. Area within peripetalous fasciole covered by densely spaced tubercules. Remainder of aboral surface covered by scattered tubercules. Details of peristome unknown. Other details of oral surface unknown.

Remarks

The possession of closed paired petaloid ambulacra and a well developed peripetalous fasciole, and no others, indicates assignment to Family Hemiasteridae. This family includes 15 genera ranging from the Upper Cretaceous-Recent, the modern forms mainly mud-dwellers (Fischer 1966). The sub-globular shape of the test, with a faint frontal sinus, two gonopores, and the very short posterior ambulacral pair suggest assignment to *Ditremaster* Munier-Chalmas, 1885. Known only from fossil, the genus ranges from the Eocene-Pliocene (Fischer 1966). It has not been possible to review Lambert and Thiéry (1924), who apparently referred thirty species to this genus (Mortensen 1950), and specific referral is deferred. Both Mortensen (1950) and Fischer (1966) have figured the type species, *D. nux* (Desor) from the Eocene of France. The test of the type species has a sub-circular outline, distinct from the ovoid outline of the Yule Island tests.

Material

Two tests: UPNG F1186, an undeformed virtually complete specimen and F1185, a weakly deformed incomplete specimen, both from the Kairuku Formation, Yule Island, Central Province, PNG. Lower Pliocene.

Family SCHIZASTERIDAE Lambert, 1905
Genus BRISASTER Gray, 1855

Type species

Brissus fragilis Düben and Koren, 1844, by original designation; Recent.

Figure 9. Spatangoid echinoids. *Brissopsis ?luzonica* (Gray, 1851). Upper Oligocene-Lower Miocene, Sagarai valley, Milne Bay Province. 9a,b, ANU 60551, aboral and oral views of internal cast. *Brisaster latifrons* (A. Agassiz, 1898). Upper Oligocene-Lower Miocene, Sagarai valley, Milne Bay Province. 9c-e, ANU 60550, aboral, oral and lateral views of internal cast. Bar scale = 0.5 cm.

Brisaster latifrons (A. Agassiz, 1898)
Figs 8d-f, 9c-e

Synonymy

Schizaster latifrons A. Agassiz, 1898, p. 81.
Hemiaster sp., F. Chapman and I. Crespin in Montgomery 1930, p. 57.
T. Mortensen (1951), A Monograph of the Echinoidea 5(2), Spatangoida II, p. 289, lists the previous synonymies.

Description

Test of small to medium size, broadly rounded almost as broad as long, F1179 measuring 34 mm x 30 mm and ANU 60550 measuring approximately 60 mm x 51 mm; test rather low, highest towards posterior, oral side gently convex. Apical system posterior; this area not well preserved to show details of genital pores; posterior petals short, about 1/3 the length of the anterior ones; frontal ambulacrum broad and moderately to deeply excavated, forming a distinct notch in anterior end of test; anterolateral petals are gently curved. Details of periproct unknown, apparently located on truncated posterior end of test. Peristome close to anterior end of test shallowly sunken, with the sunken peristomal region continuing directly to frontal notch. Peripetalous fasciole well developed in F1179; a lateral fasciole passes posteriorly to meet with an anal fasciole, that is partially preserved in this specimen. Both oral and aboral surface with uniform covering of tubercules; no large (primary) tubercules present.

Remarks

Although the apical system is not well preserved, the general shape of the test, and the arrangement of the petals and preserved fascioles distinguishes these specimens as members of Family Schizasteridae. The low shape of the test clearly distinguishes it from other schizasterids as being typical of *Brisaster* Gray, 1855. *Brisaster* includes eight species ranging from the Oligocene-Recent (Mortensen 1951; Fischer 1966). Recent species of the genus are distributed throughout the northern Atlantic, northern Pacific and South African seas from bathymetric depths of 40 to 1,300 m (Mortensen 1951).

The Sagari valley and Yule Island tests are clearly distinguishable from Oligocene *Brisaster maximus* Clark, 1937, a large species from Oregon with a test about 100 mm long and straight anterior petals (Mortensen 1951). However, both tests have several characters shared with Recent *Brisaster latifrons* (A. Agassiz, 1898), as described by Mortensen (1951), including low test height posteriorly, very short posterior petals and a broad frontal ambulacrum.

Material

Two tests: UPNG F1179, an undeformed virtually complete specimen from the Kairuku Formation, Yule Island, Central Province; and ANU 60550, an incomplete internal cast from the Padowa Beds, Wabalam Creek, northern Sagari valley, Milne Bay Province, PNG. Upper Oligocene-Lower Pliocene.

Suborder MICRASTERINA Fischer, 1966
Family BRISSIDAE Gray, 1855
Genus BRISSOPSIS L. Agassiz, 1840

Type species

Brissus lyrifer Forbes 1841, by subsequent designation of Desor, 1858; Recent, Gulf of Mexico.

Brissopsis ?luzonica (Gray, 1851)
Figs 9a,b

Synonymy

Kleinia latior Gray, 1851, p. 133.

T. Mortensen (1951), A Monograph of the Echinoidea 5(2), Spatangoida II, p. 397, lists the previous synonymies.

Description

Test of moderate size, length about 55 mm, width 44 mm, height about 22 mm; with an ovoid outline. Test outline weakly notched at the anterolateral ambulacra. Frontal notch distinct; the frontal depression deep. Details of posterior end not preserved. The anterior petals are distinctly sunken and divergent, with a tendency to parallel proximally. Pore pairs are preserved in ambulacrum IV, with outer series distinctly larger. A narrow ridge formed at the proximal end of the interambulacra 1 and 4 appears to separate the anterior and posterior petals. Posterior petals are not preserved. The frontal ambulacrum is sunken. Other details of this ambulacrum not known. Interambulacra consist of typical alternating series of plates; other details unknown. Details of apical system unknown. Peristome near anterior end of test, deeply sunken; sunken region continuing to frontal notch; other details unknown. Details of periproct unknown. Details of fascioles unknown.

Remarks

Brissopsis L. Agassiz, 1840 is an Oligocene-Recent micrasterid and a discussion of its many species is found in Mortensen (1951) and McNamara et al. (1986). At least 10 fossil species are known from the Tertiary of Europe, the Middle East, southeast Asia, Australasia and Central America. Recent species number at least 17 and are widely distributed in both the Atlantic and Indo-Pacifc, with shallow water (12 to 45 m) and deep water (130 to 2,980 m) forms known (Mortensen 1951).

Mortensen (1951: 378) considered that the arrangement of posterior petals, whether divergent or to a varying extent parallel or confluent proximally, to be an important diagnostic character amongst species of *Brissopsis*. The curvature of the anterior petals of the Sagari valley test is consistent with the development of semi-circular anterior and posterior petals on each side of the test. This petal arrangement is distinctive in *Brissopsis tatei* Hall, 1907, *Brissopsis crescenticus* Wright (1855) and *Brissopsis luzonica* (Gray, 1851) (Hall 1907; Mortensen 1951; McNamara et al. 1986). *B. tatei* is an Early-Middle Miocene species from Victoria and South Australia and *B. crescenticus*, and a nominate form var. *syriaca* Vautrin, 1933, are known from the Miocene of Malta and Syria (McNamara et al. 1986). *B. luzonica* is a Recent species widely distributed throughout the Indo-West Pacific, including off the northern coasts of Australia (Mortensen 1951; McNamara et al. 1986). The poor preservation of the Sagarai valley test does not permit a thorough consideration of affinities with closely allied species, and the specimen is tentatively referred to *B. luzonica* because of more or less conspicuous notches at the antero-lateral ambulacra and a deep anterior groove.

Nichols (1959) noted that a deep anterior groove, providing a channel for the passage of food currents from the aboral surface to the mouth, is related to the nature of the substratum inhabited. Forms with deep anterior grooves inhabit sand or sandy mud, where it is difficult to maintain a tube from the aboral surface round the anterior ambitus to the oral surface, and presumably it is necessary for spines to arch over the groove and make a roof to it (Nichols 1959).

Material

ANU 60551, an incomplete internal cast of a test with some details of ambulacrum IV from the Padowa Beds, Wabalam Creek, northern Sagari valley, Milne Bay Province, PNG. Upper Oligocene-Lower Miocene.

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APPENDIX

Collection details

Aseki locality: Collection site is in a tributary of the Kapau River, immediately east of the airfield and Lutheran Mission at Aseki village, Morobe Province, PNG. Grid Reference 111878 Aseki 1:100,000 Sheet 8183. Site is upstream of the track from Aseki to Windowi.

Sagari valley locality: Collection site is in the vicinity of Ata Ata village on the northern side of the Sagari River valley, southwest of Alotau, Milne Bay Province, PNG. Site is in the lower reaches of Wabalam Creek, about 540 stream metres downstream from its junction with Petula Creek. The reader is referred to map labelled Dwg. 958/5/2 in Lindley (1991) for additional details (collection site at survey station 813 on map).

Yule Island locality: Collection site is on the southeastern coastline of Yule Island, Central Province, PNG. Grid Reference 493258 Kubuna 1:100,000 Sheet 8280.